SPECIAL CONTRIBUTIONS.

THE PERIODICITY OF SUN SPOTS AND THE VARIATIONS OF THE MEAN ANNUAL TEMPERATURES OF THE ATMOSPHERE.

Note by M. Charles Nordmann presented by M. H. Poincaré, translated from the Comptes Rendus. Paris, June, 1903. Tome 136, page 1047.

Since the well-known memoir by Koeppen,[1] which appeared in 1873, and which embraces the period from 1830 to 1870, no complete work on this subject has been published.

By the kind advice of Mons. H. Poincaré I have attempted to study the data for the past thirty years bearing on this question which is of such great importance to celestial phyiscs and meteorology. It results from Koeppen's work that the curve of the variations of mean annual temperatures pursues a regular course only at the tropical stations, and that for regions outside of the Tropics, this curve becomes so very irregular that it is no longer possible to recognize in it any periodic course whatever.

I have, therefore, only made use of the results at tropical stations. But as it is especially during these last thirty years that meteorological observations have been everywhere diffused and systematized, I have been able to utilize much more extensive and more accurate materials than Koeppen had at his disposal. For example, whereas, on the one hand, Koeppen only had access to observations from the Indies, the Antilles, and tropical America, I have been able to utilize those for a great number of stations distributed all around the globe, so that the results obtained can really be considered as representing the average condition of all that part of the earth situated between the Tropics; on the other hand, I have had at my disposal a series of observations generally longer for each station than those possessed by Koeppen, so that, whereas, he was obliged to make use of certain series containing only six years of observation (which might be a source of error) I was able to eliminate all series not having at least eleven years of observation, that is to say the mean value of a complete period of sun spots.

The stations, for which I have utilized all the observations published since 1870, are the following, in the order of increasing east longitude:

Havana, Cuba, north, 23°; west, 82°.
Kingston, Jamaica, north, 18°; west, 76°.
Port au Prince, Hayti, north, 18°; west, 72°.
Port of Spain, Trinidad, north, 11°; west 62°.
Pernambuco, Brazil, south, 8°; west, 35°.
Free Town, Sierra Leone, north, 8°; west, 13°.
Port Louis, Mauritius, south, 20°; east, 57°.
Rodriguez Island, south, 19°; east, 63°.
Bombay, India, north, 19°; east, 73°.
Batavia, Java, south, 6°; east, 107°.
Hongkong, China, north, 22°; east, 114°.
Zi-Ka-Wei, China, north, 31°; east, 121°.
Manila, Philippines, north, 11; east, 121°.

The following table summarizes the results obtained. Column A contains, for each year, the general mean of the annual deviations from the normal, and for all the stations; this series of means has been computed by giving the weight 2 to the observations at Bombay, Batavia, Zi-Ka-Wei, Hongkong, and Manila, whose means result from a great number of daily observations and extend over a greater number of years than those of the other stations; to these latter the weight 1 has been given. The figures in column B (calculated in order to give a more homogeneous appearance to the curve of the variations and to eliminate, as far as possible, the secondary irregularities from this curve), are computed in the following manner: Each figure of this column is equal to the mean of the corresponding number in column A and to the half sum of the

figure which precedes and the figure which follows it. The column of sun spots contains opposite each year the relative numbers of spots (Wolf's numbers). The numbers in columns A and B represent hundredths of degrees centigrade:

Years.	A.	B.	Sun spots.
	°	°	
1870	−29	−22 min.	139 max.
1871	− 9	−14	111
1872	− 8	− 7	101
1873	− 4	− 9	66
1874	−22	−13	44
1875	− 6	−12	17
1876	−13	− 5	21
1877	+13	− 8	22
1878	+20	+13	3 min.
1879	0	+ 6	6
1880	+ 5	+11	32
1881	+33	+20 max.	54
1882	+ 3	+ 7	59
1883	− 9	−10	64 max.
1884	−27	−21 min.	63
1885	−20	−21	52
1886	−16	−17	25
1887	−16	− 5	13
1888	+26	+13	7
1889	+18	+15 max.	6 min.
1890	− 1	+ 6	7
1891	+19	+ 4	35
1892	− 1	− 5	73
1893	−27	−12 min.	84 max.
1894	+ 2	− 5	78
1895	+ 1	+ 7	64
1896	+25	+20	41
1897	+28	+25	26
1898	+19	+19	26
1899	+10	+18	12
1900	+33	+25 max.	9 min.

If we construct a curve by taking for abscisas the years and for ordinates the numbers in column B, and another curve by taking the same abscissas and as ordinates the numbers of the column Sun spots, but entering these latter ordinates negatively in such a way as to represent the inverse [strictly the complement] of the frequency of the sun spots, we obtain two curves of a perfectly parallel course. A more detailed discussion of the two curves only confirms their parallelism, which appears even in the most minute details; the limits of this note do not permit giving this detailed study here, but it will shortly appear in a memoir containing the details of this work.

We can, however, even now enunciate the following conclusion which results immediately from the examination of the preceding table.

The mean temperature of the earth is subject to a period substantially equal to that of the sun spots; the effect of these spots is to diminish the mean temperature of the earth; that is to say, the curve which represents the variations of the latter is parallel to the inverted curve of the frequency of the sun spots.

I take pleasure in expressing my profound gratitude to Monsieur Mascart who has kindly placed the resources of the Library of the Central Meteorological Bureau at my disposal for this investigation, and to Monsieur Angot who, with a kindness which I am happy to acknowledge, has given me the benefit of his advice, which is of much weight in these matter.

ON THE SIMULTANEOUS VARIATIONS OF SUN SPOTS AND OF TERRESTRIAL ATMOSPHERIC TEMPERATURES.[1]

By Prof. Alfred Angot, translated by Miss R. A. Edwards.

Mr. Charles Nordmann has recently published the general conclusions of a very interesting work in which, confirming and extending the results set forth by Koeppen thirty years ago, he shows the relation between the period of sun spots and the average annual temperature of the earth's atmosphere in the tropical regions.

To obtain this result Nordmann, as did Koeppen, took a cer-

[1] Zeitschrift der Oesterr. Gesellschaft für Meteorologie, t. VIII, 1873.

[1] Annuaire de la Société Météorologique de France, June, 1903, pp. 93–97.